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The Spectroscopic System Delta Ceti

First Paper

BY

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THE SPECTROSCOPIC SYSTEM DELTA CETI

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The star δ Ceti ($\alpha = 2^h34^m{\cdot}4$; $\delta = -0°6'$) was discovered by the writer to be of the β Canis Majoris type[1]. The spectral characteristics being favourable, it was soon placed on our observing programme for extensive investigation. Mr. J. F. Frédette took an active and enthusiastic part in the observations, and Mr. W. A. Thorn in the measures and reductions. A few series of observations were secured in 1919 and 1920, and a much larger number in 1921. Some of these, on extremely cold nights with skies exceedingly transparent, furnished such good star images that it was possible to reduce the time of exposure considerably, and to obtain long series of spectrograms, which are certainly among the best we ever took.

The results obtained, as can be gathered by an examination of the accompanying velocity curves, indicate a rather complicated behaviour. No two curves are alike and in some of them appear unexplained humps which, in most cases, seem real and not due to possible errors of observation or measurement. In the case of two of the best curves the spectrograms have been carefully remeasured, and the curves obtained the second time are found to agree very well with those obtained at first.

The amount of data at hand is not sufficient to formulate a satisfactory explanation of the behaviour of the star. It seems, however, that the idea suggested by Prof. P. Guthnick[2] in connection with his photo-electric investigations is worth considering. According to him the light variations of many stars are due to a combination of an Algol type variation, or variation due to eclipse (orbital motion) with a plain Cepheid variation (most likely not orbital motion). That is, the system would consist of two bodies of which one or both are Cepheid variables (the variation arising from pulsation or any other physical cause which might be brought forward to explain it), which also revolve around each other, the period of Cepheid variation being different from that of orbital motion.

In our former spectroscopic observations there are several points which tend to support this view, among which might be mentioned the fact that in β Canis Majoris[3] the period of variation of line-widths is different from that of velocity variation. The variation in line-widths, which is simple, would on this supposition be due to the physical variation in the star (which we might call Cepheid variation), while the radial velocity variation would be the expression of the combination of the two variations, physical and mechanical (which we might call orbital). The case of σ Scorpii[4] might also be capable of explanation by the two kinds of variation, one orbital with a period of approximately 34 days and one physical of very short period.

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[1] Pub. Dom. Obs., Vol. 5, p. 15.
[2] Veröffentlichungen der K. Sternwarte zu Berlin-Babelsberg, Band II, Heft 3, p. 129.
[3] L. O. B., Vol. 9, p. 159.
[4] Pub. Dom. Obs., Vol. 5, No. 7.

In the present case of δ Ceti it seems possible that the curve is the resultant of two or several fairly simple curves. To solve the problem, however, a considerable number of observations is desirable. The star will be again observed by us between September 23rd and December 31st, 1922, and if need be in 1923. A great many nights, however, are likely to be cloudy; if several observatories, equipped with spectrographs or photo-electric cells, were to collaborate in this study it would be of the greatest advantage, as long gaps in the curves might thus be filled.

The problem presented by δ Ceti is apparently closely allied to that of Cepheid variation. There are apparently in it, as well as in most stars of the β Canis Majoris type, complications which might help to throw light on the Cepheids, the puzzle of modern astrophysics.

The table of radial velocities obtained is given first and is followed by the detailed measures of some of the spectrograms. The tables are followed by drawings of the different curves, from which a better idea can be obtained of the striking differences presented.

OTTAWA RADIAL VELOCITIES OF δ CETI

Date	Julian Day	Velocity, km.	Length of exposure, minutes	Remarks
1919 Nov. 2.....	2422265·561	+ 7·9	60	
	·617	+ 3·0	25	
Nov. 9.....	272·567	+ 6·4	60	
	·621	+20·1	60	
	·664	+32·3	60	
	·711	− 3·6	55	
1920 Sept. 13.....	581·701	+21·3	60	
	·774	+ 0·5	60	
	·817	−10·8	60	
	·865	+ 8·5	60	
Sept. 14.....	582·685	+ 6·2	60	
	·729	+ 6·1	60	
	·771	− 1·9	55	
	·818	+ 9·1	55	
	·858	+ 8·7	60	
Sept. 15.....	583·710	+ 7·9	56	
	·775	+ 1·6	60	
Sept. 20.....	588·714	+ 2·4	45	
	·768	+ 8·0	60	
	·818	− 5·6	60	
	·871	− 7·9	55	
	·910	− 5·7	55	
1921 Oct. 26.....	989·580	− 5·3	54	
	·617	+ 0·9	50	
	·653	+ 8·3	50	
	·717	+ 2·2	50	
	·763	− 1·6	50	
	·803	− 5·8	50	
	·842	−10·8	50	

OTTAWA RADIAL VELOCITIES OF δ CETI—*Continued*

Day	Julian Day	Velocity, km.	Length of exposure, minutes	Remarks
1921 Oct. 27.....	2422990·540	+ 8·3	60	
	·578	− 6·4	50	
	·615	−10·9	50	
	·751	−10·9	70	
Oct. 30.....	993·581	− 1·8	60	
	·620	−10·2	50	
	·656	− 4·8	50	
	·730	− 1·1	70	
	·785	− 1·9	80	
Nov. 2.....	996·538	+ 0·2	50	
	·574	− 3·0	50	
	·609	+ 6·6	50	
	·645	+ 4·8	50	
	·718	+ 5·8	50	
	·754	+21·6	50	
	·792	+21·7	55	
Nov. 7.....	001·526	−10·5	60	
	·566	+16·1	50	
	·608	+ 9·9	50	
	·645	+ 3·7	50	
	·722	− 1·8	50	
	·758	+25·1	50	Remeasure +31·1
	·794	− 2·0	50	
	·831	− 2·8	50	
	·868	− 7·6	50	
Nov. 8.....	002·571	+14·0	60	
	·610	+ 3·2	50	
	·646	− 6·7	50	
	·733	+21·0	60	
Nov. 15.....	009·625	+ 9·5	50	
	·672	− 4·1	50	
	·727	+ 6·4	60	
Nov. 16.....	010·560	+ 7·0	39	
Nov. 20.....	014·488	+15·1	50	
	·524	+13·6	50	
	·575	− 1·3	50	
	·612	+ 3·2	50	
	·649	− 0·3	50	
Nov. 22.....	016·709	+ 4·3	50	
Nov. 24.....	018·620	−13·8	50	
	·656	− 3·8	50	
Nov. 28.....	022·565	+ 8·1	20	Clouds.
	·659	+ 7·9	50	
	·714	+ 7·5	50	
	·751	+10·8	50	
	·791	+ 6·5	60	
Dec. 4.....	028·458	+ 3·5	50	
	·489	+13·0	40	
	·518	+13·4	40	
	·552	+ 9·9	40	
	·583	+ 0·6	40	
	·615	+ 4·4	45	
	·710	+ 2·4	50	

OTTAWA RADIAL VELOCITIES OF δ CETI—*Continued*

Date	Julian Day	Velocity, km.	Length of exposure, minutes	Remarks
1921 Dec. 5.....	2423029·626	+17·2	40	
	·651	+ 7·9	32	
	·769	− 3·1	60	
Dec. 6.....	030·480	+12·7	40	
	·508	+ 5·0	40	
	·537	+ 0·8	40	
	·574	− 3·7	40	
	·632	− 0·4	40	
	·657	− 0·6	30	
	·708	−26·7	40	Poor plate.
Dec. 7.....	031·484	− 5·5	30	
	·506	+ 5·9	30	
	·528	+ 1·5	30	
	·547	+ 5·3	25	
	·562	+ 4·6	20	
	·576	+ 7·2	20	
	·593	+17·3	20	
	·608	− 5·2	25	
	·629	+ 4·5	30	
	·648	+ 4·3	20	
	·662	+10·6	20	
	·701	− 0·4	25	
	·721	+ 0·4	25	
	·743	−20·7	30	Poor plate.
Dec. 8.....	032·470	− 5·3	25	
	·487	+ 8·7	20	
	·529	+11·4	20	
	·544	+ 7·7	20	
	·558	+ 6·6	20	
	·624	− 4·4	20	
	·640	− 0·2	20	
	·657	−15·1	20	
Dec. 13.....	037·435	+22·7	60	
	·470	+ 2·2	35	
Dec. 14.....	038·433	+12·5	40	
	·459	+24·1	30	
	·536	− 3·5	30	
	·591	−15·0	30	
Dec. 15.....	039·429	+ 8·1	30	Remeasure + 5·5
	·451	− 1·1	25	+ 0·9
	·468	+ 2·2	20	+ 7·5
	·483	+10·4	20	+12·3
	·496	+ 7·1	12	+ 2·8
	·506	+16·7	12	+11·8
	·516	+ 1·3	12	+17·4 Weak
	·525	+ 8·6	12	+ 3·2
	·534	+ 7·0	12	+ 7·2
	·543	+ 0·1	12	− 2·8
	·552	− 7·0	12	+ 1·5
	·561	+ 4·2	12	− 2·6
	·570	− 8·1	12	
	·579	− 5·8	12	− 6·3
	·589	− 1·6	14	− 5·1

OTTAWA RADIAL VELOCITIES OF δ CETI—*Continued*

Date	Julian Day	Velocity, km.	Length of exposure, minutes	Remarks
1921 Dec. 15—*Con.*....	2423039·599	+ 0·4	12	− 1·1
	·608	− 5·4	12	− 6·2
	·617	+ 2·3	12	+ 0·9
	·626	+ 2·5	12	+ 7·7
	·645	+ 6·9	12	+ 4·2
	·655	+ 4·7	12	+ 1·3
	·665	−10·1	12	−12·4
	·699	− 2·6	12	+ 2·6
	·711	−13·0	12	−17·9
	·733	−26·8	16	−34·0 Weak
	·747	− 8·7	20	+ 9·4 Very weak
Dec. 19.....	043·431	+12·5	30	
	·449	+ 9·1	20	
	·465	+ 5·1	20	
	·480	+ 7·3	20	
	·494	+ 3·2	15	
	·506	+ 9·5	15	
	·518	+ 9·2	15	
	·530	− 5·4	15	
	·542	+ 7·4	15	
	·553	− 1·8	15	
	·565	− 8·7	15	
	·576	− 0·5	15	
	·587	− 2·5	15	
	·599	+ 1·2	15	
	·610	−18·3	15	
	·621	−12·2	15	
	·633	+ 2·1	15	
	·644	− 5·9	15	
	·658	0·0	20	
	·713	− 8·1	33	
Dec. 21.....	045·431	+19·8	30	Remeasure +13·1
	·451	+10·0	20	+ 9·9
	·470	+18·6	30	+11·8
	·489	+13·8	20	+20·9
	·509	+ 6·5	18	+ 4·2
	·524	+ 5·2	15	+ 0·7
	·536	+ 6·3	15	+ 4·3
	·547	− 3·2	15	− 2·2
	·558	+ 0·3	15	− 3·1
	·570	+ 0·4	15	+ 6·7
	·581	+ 5·8	15	+14·9
	·592	+10·9	15	+ 9·3
	·604	+ 2·8	15	+ 5·7
	·615	+ 7·9	15	+ 6·1
	045·626	+ 9·4	15	− 0·2
	·637	+ 4·4	15	+ 7·5
	·649	+ 9·1	15	+11·8
	·660	− 1·4	15	+ 5·2
	·703	− 7·7	20	− 6·1
	·720	−16·7	20	+11·9 Poor
Dec. 22.....	046·534	+ 9·6	20	
	·548	+ 3·4	16	

OTTAWA RADIAL VELOCITIES OF δ CETI—*Concluded*

Date	Julian Day	Velocity, km.	Length of exposure, minutes	Remarks
1921 Dec. 22—*Con*....	2423046·565	+ 2·7	15	
	·576	+ 8·8	15	
Dec. 25.....	049·436	+16·5	40	
	·458	+14·2	20	
	·473	+10·6	20	
	·487	+31·5	18	Remeasure +25·8
	·503	+12·4	15	+12·3
	·515	+ 0·3	15	
	·527	+ 0·2	20	
	·542	− 1·9	20	
	·557	+12·8	18	Remeasure +10·3
	·570	− 6·0	18	
	·583	− 5·8	18	
	·598	− 1·3	18	
	·611	+16·5	18	Remeasure +14·9
	·626	+ 2·9	20	
	·644	+10·1	20	
	·658	−13·0	20	Remeasure −14·3
Dec. 29.....	053·437	+16·4	30	
	·458	+14·9	25	
	·477	+16·8	25	
	·498	+12·4	20	
	·512	+ 9·7	18	
	·525	+ 4·7	16	
	·537	+12·5	15	
	·557	− 5·8	15	
	·569	−18·5	15	
	·581	−14·8	18	
	·595	+ 0·3	20	

Among the most peculiar curves that the above velocities furnish are those:

(1) Of 1921, November 7th, where one of the observations differs considerably from the others; this, of course, may be accidental, although the plates are good and furnish velocities from the different lines which agree very well with each other.

(2) Of 1921, December 15th, 19th and 21st, where a succession of rapid maxima and minima can hardly be doubted.

(3) Of 1921, December 25th, which gives a fairly smooth curve, with, however, four observations that do not agree, although their detailed measures are very good. Whether these are real or accidental it is impossible to say.

The detailed radial velocity measure for three plates of November 7th, and for the almost complete series of December 15th, are given in the following pages so that the reader may judge of the value of the measures.

Taking for instance the spectrograms of December 15th which, carefully remeasured by a different observer, give exactly the same shape of curve, it seems plausible that these rapid rises from a minimum to a maximum, which apparently do not repeat themselves periodically, and which occur during an interval of approximately one hour or perhaps less, are not due, at least entirely, to orbital motion; they agree better with the nature of eruptions such as those of huge prominences which occur on our Sun.

PRINCIPAL LINES AND CORRESPONDING MICROMETER READINGS

Element	λ	Micrometer reading at 0° centigrade
H	3889·15	15·464
K (Ca)	3933·825	19·840
He	3964·875	22·747
H (Ca)	3968·625	23·091
He	3970·177	23·233
N	3995·26	25·488
He	4009·417	26·731
He	4026·352	28·193
?	4069·700	31·805
O	4076·080	32·322
Hδ	4101·890	34·374
He	4121·016	35·858
He	4143·928	37·595
He	4169·183	39·460
O	4190·060	40·965
C	4267·301	46·251
?	4276·200	46·835
O	4317·272	49·455
Hγ	4340·634	50·899
He	4388·100	53·734
He	4471·676	58·423
Mg	4481·397	58·945
Si	4552·636	62·633
Si	4567·897	63·393
He	4713·308	70·151
Hβ	4861·527	76·248
He	4922·10	78·542

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS

Plate 9897
1921, Nov., 7·722

Reduced micrometer reading	Velocity km.	Weight
28·195	+ 1·7	1
34·409	+32·5	1
35·870	+11·4	1
37·627	+31·0	1
46·244	− 7·5	1
50·900	+ 1·1	4
53·730	− 4·7	3
58·426	+ 3·7	6
70·160	+13·1	2
76·228	−31·8	1

Weighted mean	+ 3·6
Va	− 5·0
Vd	− 0·1
Curv	− 0·3
Radial velocity	− 1·8

Plate 9898
1921, Nov., 7·758

Reduced micrometer reading	Velocity km.	Weight
34·408	+31·6	1
35·875	+16·2	1
37·626	+30·1	3
46·286	+37·4	2
50·929	+33·7	1
53·771	+43·3	4
58·455	+39·9	8
70·185	+49·6	2
76·251	+ 4·8	1

Weighted mean	+36·6
Va	− 5·0
Vd	− 0·2
Curv	− 0·3
Radial velocity	+31·1

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Continued*

Plate 9899
1921, Nov., 7·794

Reduced micrometer reading	Velocity km.	Weight
28·180	−11·3	1
34·373	− 0·9	1
37·592	− 2·9	6
53·753	+22·2	4
58·427	+ 5·0	3
76·237	−17·5	1

Weighted mean	+ 3·5
Va	− 5·0
Vd	− 0·2
Curv	− 0·3
Radial velocity	− 2·0

Plate 9989
1921, Dec., 15·429

Reduced micrometer reading	Velocity km.	Weight
37·616	+20·4	3
50·923	+27·1	2
53·759	+29·3	9
58·448	+31·0	7
58·975	+37·5	2
76·274	+41·3	1

Weighted Mean	+29·7
Va	−21·6
Vd	+ 0·3
Curv.	− 0·3
Radial velocity	+ 8·1

Plate 9990
1921, Dec., 15·451

Reduced micrometer reading	Velocity, km.	Weight
28·215	+19·1	1
37·614	+18·4	3
46·274	+24·6	1
50·914	+17·0	3
53·756	+25·7	7
58·427	+ 5·0	3
76·269	+33·4	2

Weighted mean	+20·6
Va	−21·6
Vd	+ 0·2
Curv	− 0·3
Radial velocity	− 1·1

Plate 9991
1921, Dec., 15·468

Reduced micrometer reading	Velocity, km.	Weight
28·226	+28·7	2
37·625	+29·1	2
46·276	+26·7	1
50·929	+33·9	2
53·754	+23·4	7
58·429	+ 7·4	3
70·168	+24·8	1
76·266	+28·6	2

Weighted mean	+23·9
Va	−21·6
Vd	+ 0·2
Curv	− 0·3
Radial velocity	+ 2·2

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Continued*

Plate 9992
1921, Dec., 15·483

Reduced micrometer reading	Velocity, km.	Weight
28·232	+33·9	1
34·398	+22·3	2
37·616	+20·4	5
39·478	+17·8	1
50·915	+18·1	3
53·762	+32·8	7
58·464	+50·8	4
70·183	+46·7	1
76·292	+70·0	1

Weighted mean	+32·1
Va	−21·6
Vd	+ 0·2
Curv.	− 0·3
Radial velocity	+10·4

Plate 9993
1921, Dec., 15·496

Reduced micrometer reading	Velocity, km.	Weight
37·622	+26·2	2
50·939	+45·2	1
53·757	+26·9	4
58·448	+31·0	3
70·167	+23·4	2

Weighted mean	+28·8
Va	−21·6
Vd	+ 0·2
Curv.	− 0·3
Radial velocity	+ 7·1

Plate 9994*
1921, Dec., 15·506

Reduced micrometer reading	Velocity, km.	Weight
53·772	+44·5	4
58·452	+36·0	6
70·169	+26·3	1
76·274	+41·3	1

Weighted mean	+38·5
Va	−21·6
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	+16·7

*(Very good plate, but one-half of it, which would have contained the lines below 50, did not develop.)

Plate 9995
1921, Dec., 15·516

Reduced micrometer reading	Velocity, km.	Weight
34·397	+21·4	2
39·476	+15·8	4
46·271	+21·4	1
50·928	+32·8	1
53·749	+17·5	3
58·450	+33·5	2
70·192	+59·9	1
76·252	+ 6·4	1

Weighted mean	+23·1
Va	−21·6
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	+ 1·3

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Continued*

Plate 9996
1921, Dec., 15·525

Reduced micrometer readings	Velocity, km.	Weight
28·223	+26·1	1
32·347	+22·8	1
34·409	+32·5	1
37·627	+31·0	2
50·930	+35·0	2
53·765	+36·3	2
58·453	+37·2	3
70·154	+ 4·4	2
76·279	+49·3	1

Weighted mean	+30·4
Va	−21·6
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	+ 8·6

Plate 9997
1921, Dec., 15·534

Reduced micrometer reading	Velocity, km.	Weight
28·221	+24·4	2
35·886	+26·6	1
37·625	+29·1	5
46·272	+22·5	1
50·922	+26·0	4
58·452	+36·0	4
63·423	+39·9	1
70·162	+16·1	1

Weighted mean	+28·8
Va	−21·6
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	+ 7·0

Plate 9998
1921, Dec., 15·543

Reduced micrometer reading	Velocity, km.	Weight
28·210	+14·8	1
37·620	+24·2	3
58·441	+22·3	6
58·955	+12·5	1
70·156	+ 8·8	1
76·275	+42·9	1

Weighted mean	+22·0
Va	−21·7
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	+ 0·1

Plate 9999
1921, Dec., 15·552

Reduced micrometer reading	Velocity, km.	Weight
35·874	+15·2	3
37·611	+15·5	2
49·470	+16·6	1
50·912	+14·7	3
58·435	+14·9	3
70·159	+11·7	1

Weighted mean	+14·9
Va	−21·7
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	− 7·0

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Continued*

Plate 10000
1921, Dec. 15·561

Reduced micrometer reading	Velocity, km.	Weight
28·214	+18·3	1
35·902	+41·8	1
40·992	+28·0	1
53·738	+ 4·7	1
58·450	+33·5	4
70·165	+20·4	3

Weighted mean	+26·2
Va	−21·7
Vd	0·0
Curv	− 0·3
Radial velocity	+ 4·2

Plate 10001
1921, Dec., 15·570

Reduced micrometer reading	Velocity, km.	Weight
37·608	+12·6	2
46·259	+ 8·6	1
50·912	+14·7	1
53·764	+35·1	1
58·423	0·0	1

Weighted mean	+13·9
Va	−21·7
Vd	0·0
Curv	— 0·3
Radial velocity	− 8·1

Plate 10002
1921, Dec., 15·579

Reduced micrometer reading	Velocity, km.	Weight
34·394	+18·6	1
37·617	+21·3	2
53·761	+31·6	3
58·427	+ 5·0	3
70·155	+ 5·8	1
76·249	+ 1·6	1

Weighted mean	+16·2
Va	−21·7
Vd	0·0
Curv	− 0·3
Radial velocity	− 5·8

Plate 10003
1921, Dec., 15·589

Reduced micrometer reading	Velocity, km.	Weight
34·406	+29·8	1
35·867	+ 8·6	2
37·611	+15·5	4
46·283	+34·2	1
50·920	+23·7	2
53·751	+19·9	4
58·442	+23·6	3
76·264	+25·4	1

Weighted mean	+20·4
Va	−21·7
Vd	0·0
Curv	— 0·3
Radial velocity	− 1·6

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Continued*

Plate 10004
1921, Dec., 15·599

Reduced micrometer reading	Velocity, km.	Weight
28·240	+40·9	1
37·598	+ 2·9	1
53·752	+21·1	3
58·429	+ 7·4	2
62·657	+31·4	2
70·178	+39·4	1

Weighted mean	+22·4
Va	−21·7
Vd	0·0
Curv	− 0·3
Radial velocity	+ 0·4

Plate 10005
1921, Dec., 15·608

Reduced micrometer reading	Velocity, km.	Weight
37·595	0·0	2
50·945	+52·0	1
53·740	+ 7·0	3
58·437	+17·4	6
62·658	+32·7	1
70·167	+23·4	1

Weighted mean	+16·7
Va	−21·7
Vd	− 0·1
Curv	− 0·3
Radial velocity	− 5·4

Plate 10006
1921, Dec., 15·617

Reduced micrometer reading	Velocity, km.	Weight
28·232	+33·9	1
34·377	+ 2·8	1
37·630	+33·9	3
50·941	+47·5	1
53·738	+ 4·7	3
58·448	+31·0	3

Weighted mean	+24·4
Va	−21·7
Vd	− 0·1
Curv	− 0·3
Radial velocity	+ 2·3

Plate 10007
1921, Dec., 15·626

Reduced micrometer reading	Velocity, km.	Weight
28·215	+19·1	1
34·390	+14·9	1
37·616	+20·4	1
46·265	+15·0	2
50·928	+32·8	2
53·773	+45·6	2
58·434	+13·6	3
70·177	+38·0	1

Weighted mean	+24·6
Va	−21·7
Vd	− 0·1
Curv	− 0·3
Radial velocity	+ 2·5

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Continued*

Plate 10008
1921, Dec., 15·645

Reduced micrometer reading	Velocity, km.	Weight
28·216	+20·0	1
34·414	+37·2	1
35·867	+ 8·6	4
37·649	+52·4	1
50·916	+19·2	1
53·759	+29·2	3
58·462	+48·4	3
62·660	+35·4	2
76·265	+27·0	1

Weighted mean	+29·0
Va	−21·7
Vd	− 0·1
Curv	− 0·3
Radial velocity	+ 6·9

Plate 10009
1921, Dec., 15·655

Reduced micrometer reading	Velocity, km.	Weight
34·409	+32·5	2
37·624	+28·1	2
50·930	+35·0	1
53·754	+23·4	2
58·450	+33·5	2
70·166	+21·9	3
76·257	+14·3	1

Weighted mean	+26·9
Va	−21·7
Vd	− 0·2
Curv	− 0·3
Radial velocity	+ 4·7

Plate 10010
1921, Dec., 15·665

Reduced micrometer reading	Velocity, km.	Weight
35·879	+19·9	1
46·266	+16·1	2
50·902	+ 3·4	1
53·731	− 3·5	3
58·434	+13·6	3
70·176	+36·5	1
76·262	+22·3	1

Weighted mean	+12·1
Va	−21·7
Vd	− 0·2
Curv	− 0·3
Radial velocity	−10·1

Plate 10011
1921, Dec., 15·699

Reduced micrometer reading	Velocity, km.	Weight
31·827	+20·0	1
35·883	+23·7	2
37·616	+20·4	3
39·454	− 5·9	3
46·261	+10·7	2
46·869	+37·8	2
50·939	+45·2	2
53·768	+39·8	3
58·433	+12·4	4
70·151	+ 1·5	3
76·272	+38·2	1

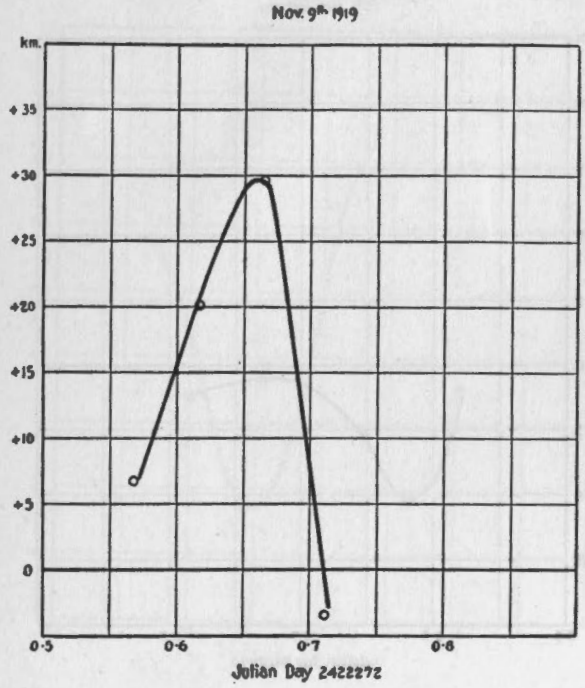
Weighted mean	+19·6
Va	−21·7
Vd	− 0·2
Curv	− 0·3
Radial velocity	− 2·6

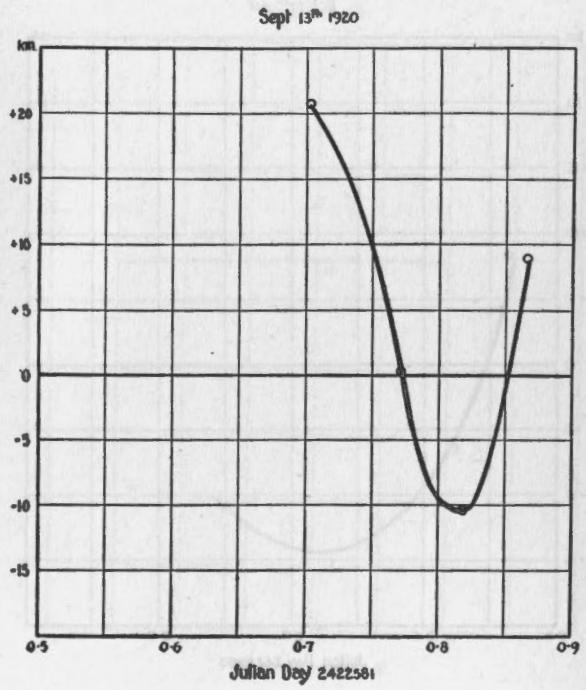
DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Concluded*

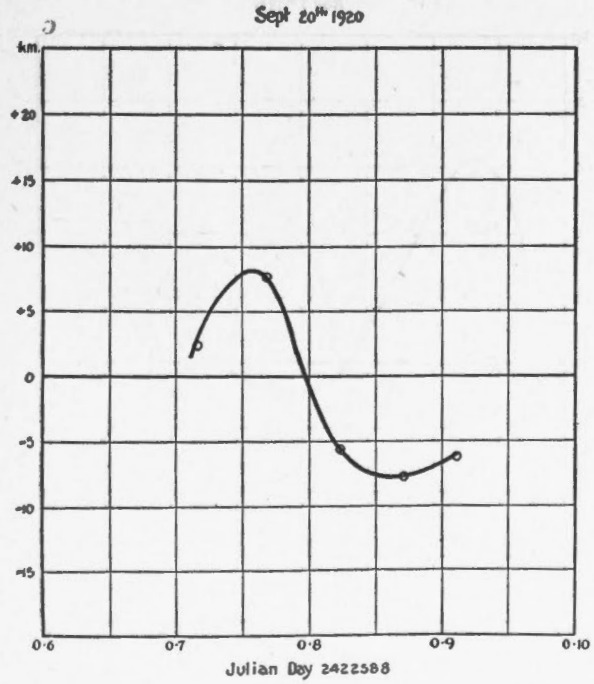
Plate 10012
1921, Dec., 15·711

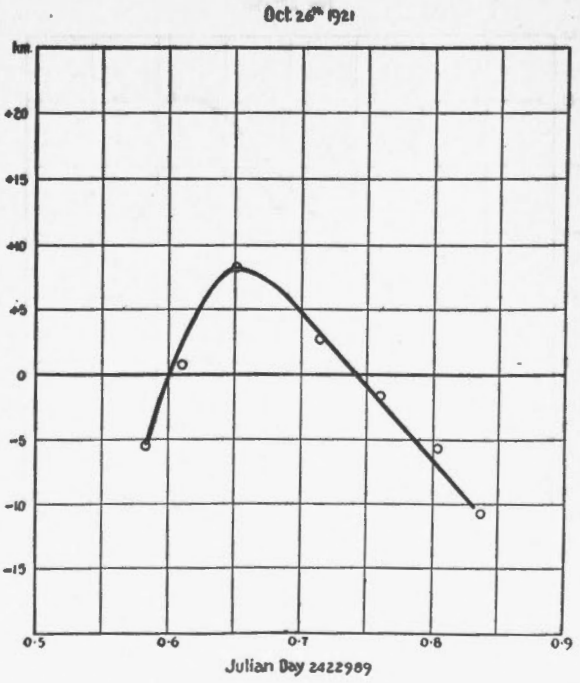
Reduced micrometer reading	Velocity, km.	Weight
35·876	+17·1	3
37·602	+ 6·8	3
50·911	+13·6	1
53·731	− 3·5	2
58·432	+11·2	3

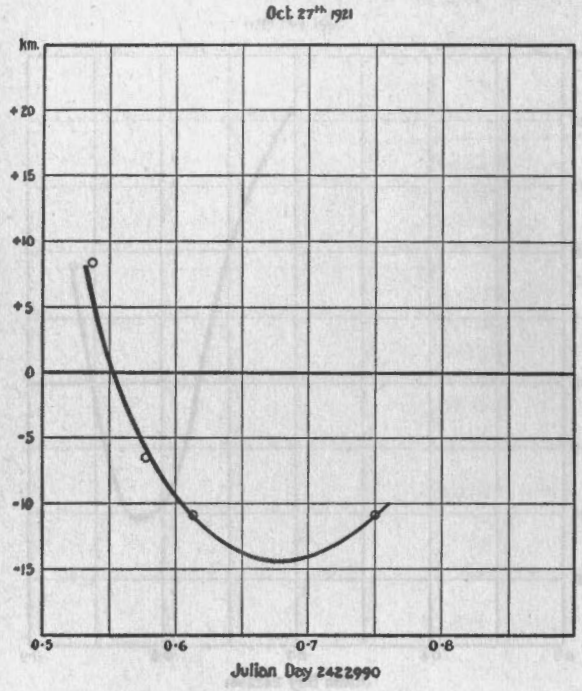
Weighted mean	+ 9·3
Va	−21·7
Vd	− 0·3
Curv	− 0·3
Radial velocity	−13·0

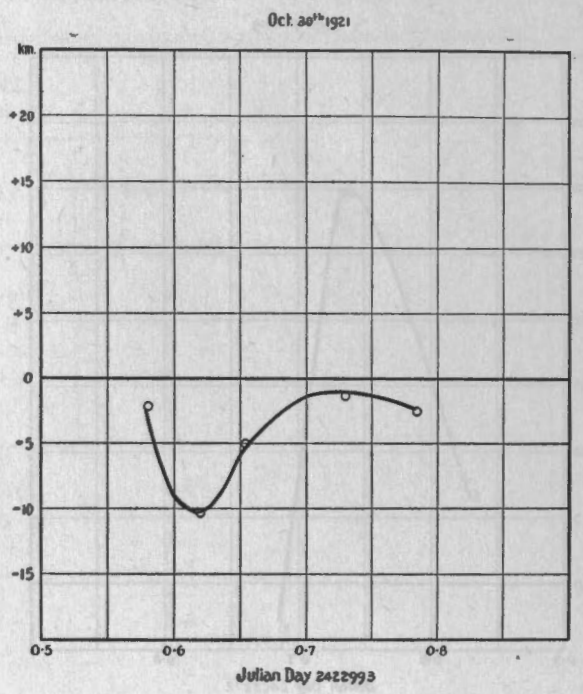

Nov. 9th 1919
km.
+35
+30
+25
+20
+15
+10
+5
0
0·5
0·6
0·7
0·8
Julian Day 2422272

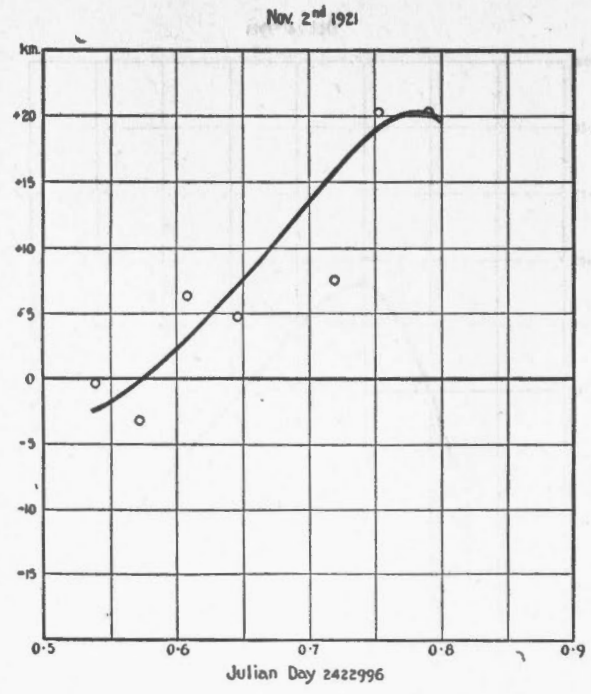

Sept 13th 1920
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
0·9
Julian Day 2422581

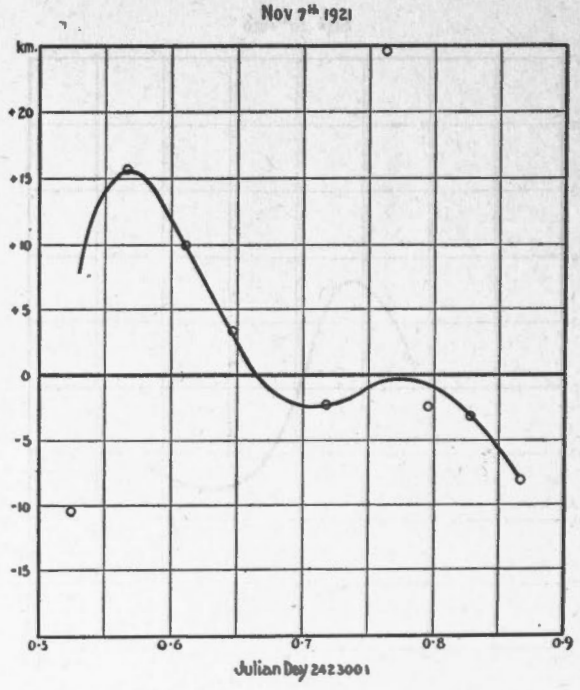

Sept 20th 1920
km.
+20
+15
+10
+5
0
-5
-10
-15
0·6
0·7
0·8
0·9
0·10
Julian Day 2422588

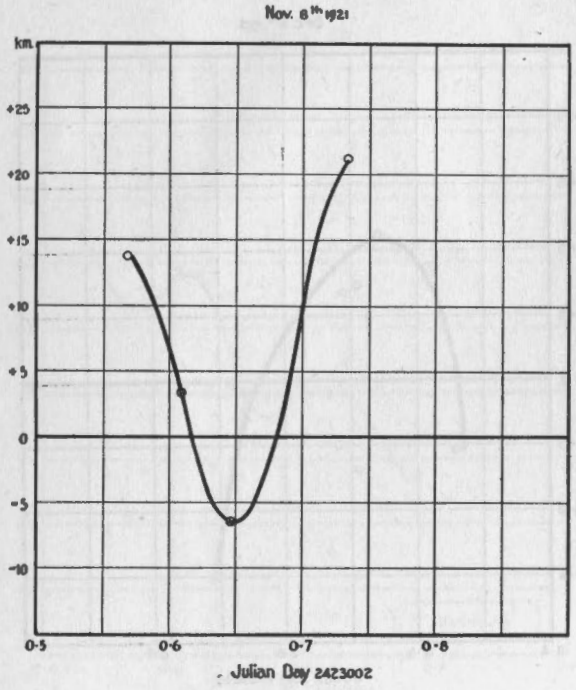

Oct 26th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
0·9
Julian Day 2422989

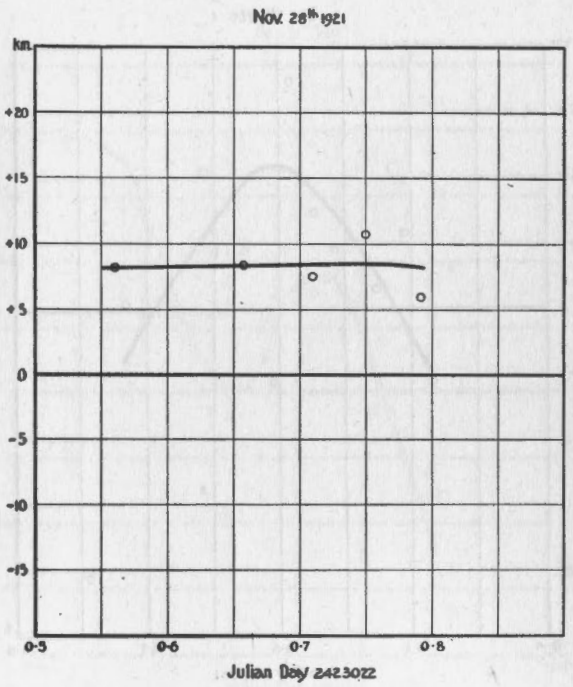

Oct. 27th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
Julian Day 2422990

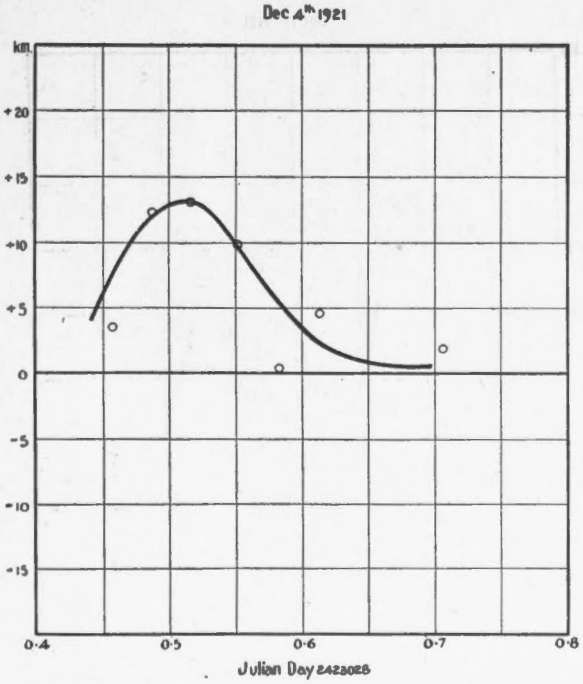

Oct. 30th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
Julian Day 2422993

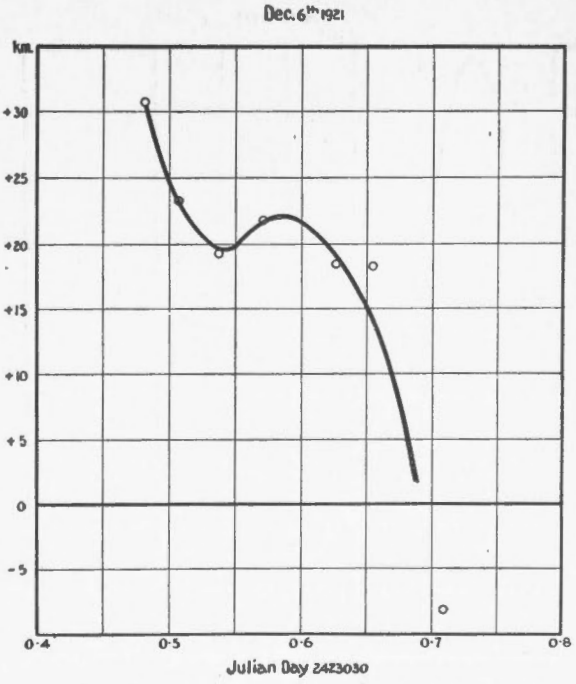

Nov. 2nd 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
0·9
Julian Day 2422996

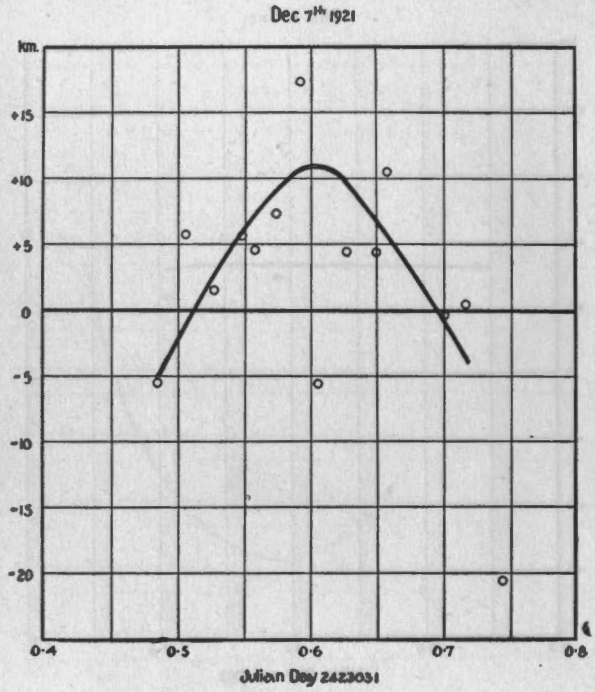

Nov 7th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
0·9
Julian Day 2423001

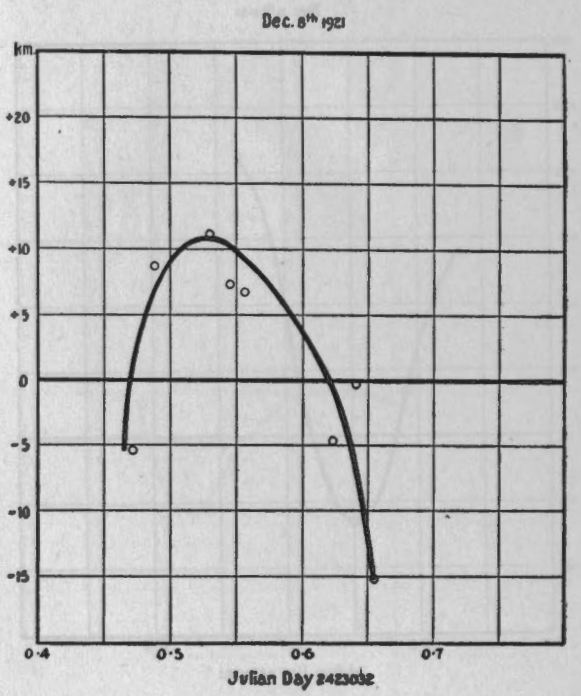

Nov. 8th 1921
km.
+25
+20
+15
+10
+5
0
-5
-10
0·5
0·6
0·7
0·8
Julian Day 2423002

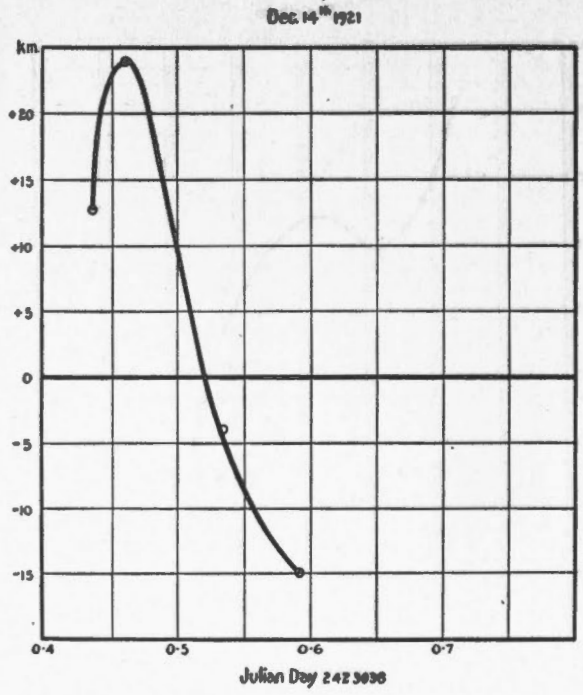

Nov. 28th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·5
0·6
0·7
0·8
Julian Day 2423022

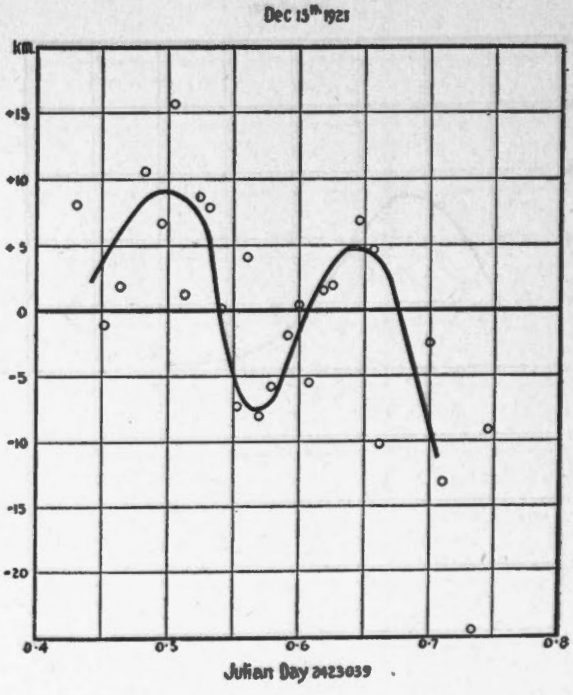

Dec. 4th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·4
0·5
0·6
0·7
0·8
Julian Day 2423028

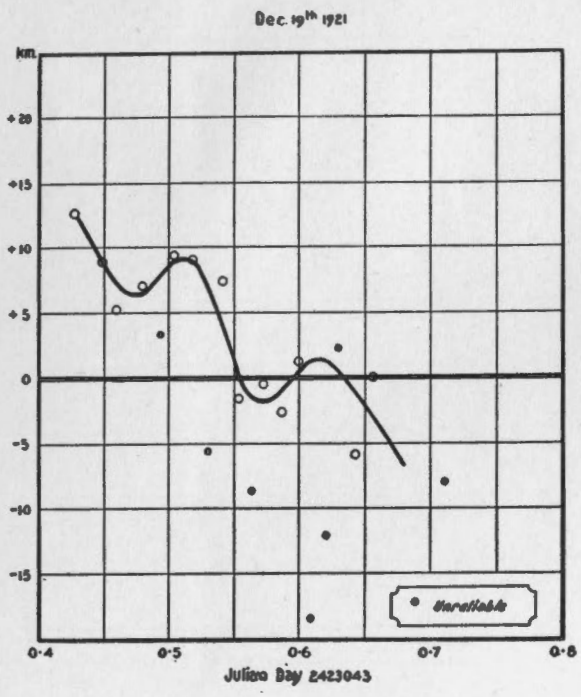

Dec. 6th 1921
km.
+30
+25
+20
+15
+10
+5
0
-5
0·4
0·5
0·6
0·7
0·8
Julian Day 2423030

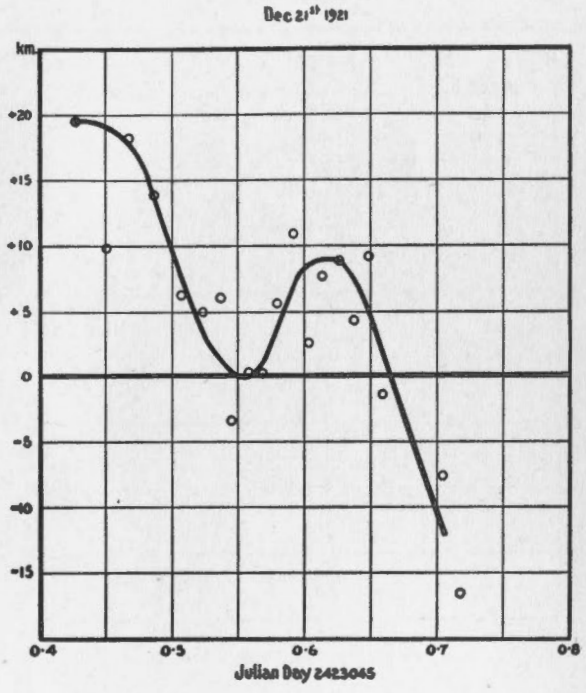

Dec 7th 1921
km.
+15
+10
+5
0
-5
-10
-15
-20
0·4
0·5
0·6
0·7
0·8
Julian Day 2423031

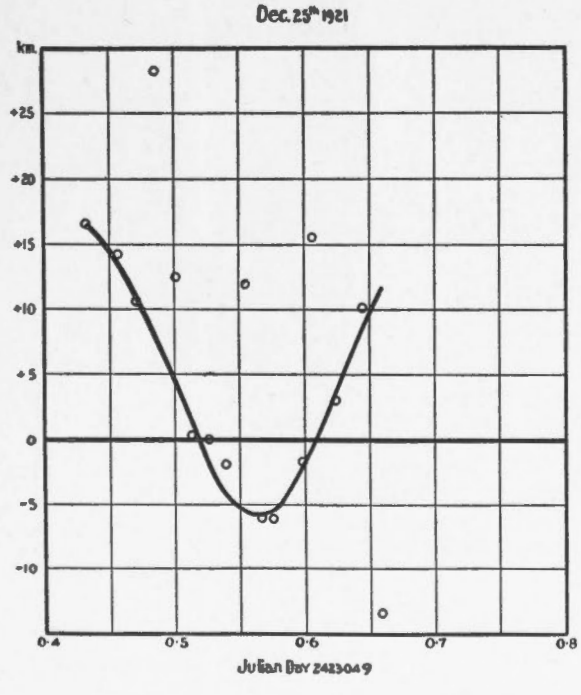

Dec. 8th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·4
0·5
0·6
0·7
Julian Day 2423032

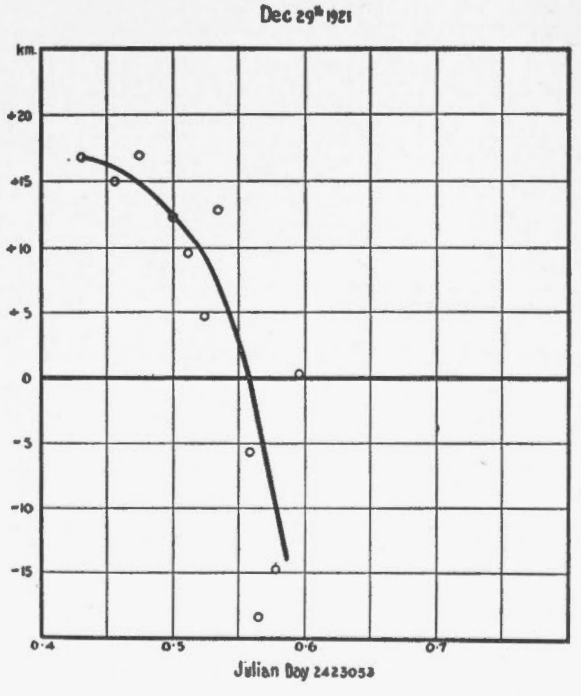

Dec. 14th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·4
0·5
0·6
0·7
Julian Day 2423038


Dec 15th 1921
km.
+15
+10
+5
0
-5
-10
-15
-20
0·4
0·5
0·6
0·7
0·8
Julian Day 2423039


Dec. 19th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·4
0·5
0·6
0·7
0·8
Julian Day 2423043


Dec 21st 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·4
0·5
0·6
0·7
0·8
Julian Day 2423045


Dec. 25th 1921
km.
+25
+20
+15
+10
+5
0
-5
-10
0·4
0·5
0·6
0·7
0·8
Julian Day 2423049


Dec 29th 1921
km.
+20
+15
+10
+5
0
-5
-10
-15
0·4
0·5
0·6
0·7
Julian Day 2423053